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High Performance Commercial Building Systems

The Air Handling Systems Functional Testing Guide: A Work in Progress

Element 5. Integrated Commissioning and Diagnostics
Project 2.1 - Commissioning and Monitoring for New Construction
Task 2.1.1 - Functional Test Guide and Test Procedures

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Synopsis

At the 9th National Conference on Building Commissioning, the concept of a functional test guide was presented in a working session that was focused on recent work by PG&E, which had resulted in an accumulation of existing functional testing information into a searchable library called the Commissioning Test Protocol Library or CTPL. The purpose of the working session was to elicit feedback from interested stakeholders regarding the CTPL and to explore how useful an educational guide would be as a complement to the library. The session also included discussions regarding what users would like to see in the guide. Workshop attendees discussed the issues of protocol requirements, product functionality, and product management.

A year later, progress has been made toward the development of a functional testing guide for air handling equipment that will be educational, user-friendly, and technically sophisticated. The guide contains enormous amounts of information, organized in an easy-to-navigate set of hyperlinked documents including links the CTPL. The CTPL links allow the user to interactively view test procedures and their related educational information and customize the procedures to their specific project requirements and save them to their own library of tests.

This paper discusses the evolution of the research project, its relationship to the CTPL, and the current status of the guide. It is presented as a work in progress, in hope that conference attendees will provide further feedback on content and navigation features, to help make the guide a useful tool in ensuring high-quality, cost-effective commissioning efforts.

About the Author(s)

David Sellers, PE, is a Senior Project Engineer at PECI. His experience includes over 24 years of system design, installation, operation, and analysis focusing on HVAC systems. In the course of his career, he has had significant involvement in the field including trouble-shooting, system optimization, building automation system control programming, testing and balancing, energy auditing and commissioning. His expertise includes developing and implementing new designs and system modification strategies to reduce energy consumption and improve overall plant energy performance in both new and existing buildings. He is currently involved with LEED™ New Construction Commissioning of the Seattle Federal Courthouse and the Honda NW Regional Facilities and retrocommissioning and planning for several projects at the Center for Building Performance and Diagnostics in addition to working with the PECI engineering staff on the development of the Functional Test Guide.

The Air Handling Systems Functional Testing Guide

Functional tests are a set of detailed instructions for building commissioning that demand extensive HVAC system knowledge to write and perform. Understanding the energy use implications and theory behind the test procedures, estimating the costs and benefits of doing a particular test, implementing the tests correctly, and resolving problems require years of field experience. As part of a large research project now underway, a practical guide is being developed that communicates this knowledge. This paper presents the components and intended use of the *Functional Testing Guide and Model Functional Test for Air Handling Systems*. A series of model functional tests, starting at the outdoor air intake section and proceeding through the air handling unit, distribution system, and terminal equipment and ending at the exhaust air discharge point, are provided for many commonly installed air handling system configurations. The model functional tests contain advice for tailoring the test procedures to specific system configurations, desirable and undesirable testing outcomes, a calculation appendix, references to other resources, and examples of completed test forms. The guide is an educational resource, with background information that clarifies the principles behind testing configurations and results. The functional tests have been selected from an extensive commissioning test protocol library (CPTL) compiled by Pacific Gas and Electric in 2001. The guide also includes a design guideline for the selection of control and monitoring points and a design intent documentation form.

Introduction and Background

As mentioned previously, the concept of a functional test guide was presented in a working session at the 9th National Conference on Building Commissioning. The feedback from that session, coupled with the results of other peer discussions resulted in the decision to proceed with the development of a Functional Testing Guide for Air Handling Systems. The goal of the development was to provide a tool that would supplement the CTPL by providing an educational component. The project also targeted the development of additional functional tests aimed at filling gaps identified in the CTPL as the guide was developed.

This project is sponsored by the California Energy Commission's (CEC) Public Interest Energy Research Program (PIER) with co-funding by the U.S. Department of Energy. The Functional Test Guide is part of Lawrence Berkeley National Laboratory's High Performance Commercial Building Systems (HPCBS, see buildings.lbl.gov/cec) in Element 5, Integrated Commissioning and Diagnostics. The objective of the overall project is to assemble and develop tools, test procedures and guides needed by owners, operators, designers, and commissioning providers to perform tests, analyze results and operate buildings efficiently. The initial version of the guideline will be out for review in the summer of 2002.

The original goal of this task was to compile a library of functional test procedures. Because recent work by Pacific Gas and Electric (PG&E) has resulted in near completion of this goal, the goal has evolved to include a Functional Test Guide/Model Test (the FT Guide) as a companion document. PG&E's work brings together the best publicly available commissioning test procedures in the industry. With the addition of the FT Guide, library users will better

understand the philosophy, thinking, and cost effectiveness behind a variety of select test procedures as well as the energy implications of problems that commissioning can identify in new construction. The CTPL provides information regarding *How* and *What* to test. The FT Guide will supplement this information by providing information on *Why* and *When* to test to aid the user in deciding on the appropriate level of testing for a given project. This will add significantly to the robustness of the test library. The commissioning test library together with the FT Guide will also provide direction toward standardization and quality control, which continues to be an overarching issue for this industry.

PG&E's Commissioning Test Protocol Library

Overview

In an effort to promote commissioning among its customers, PG&E has created a "Commissioning Test Protocol Library"(CTPL). The currently available Release 1.3 represents the final product for the current project and funding cycle. Future PG&E projects as well as the work associated with the FT Guide project will enhance this release. The library includes commissioning protocols (verification checks and functional tests) and documents related to commissioning (articles, guidelines, etc).

The library is currently made up of the four components below.

- A collection of non-copyrighted commissioning protocols (test procedures).
- A database containing review summaries of commissioning protocols (copyrighted and non-copyrighted).
- A draft of protocol templates.
- A library for archiving new commissioning protocols.

The last feature noted will be used by the FT Guide to allow the user to create their own custom library of protocols and add other protocols to their copy of the CTPL.

PG&E performed a literature search to identify and collect both copyrighted and publicly available commissioning test protocols. They were cataloged using a detailed review matrix and indexed in a database (Microsoft Access©). Microsoft Access© 97 is the mechanism for accessing the CTPL. All protocols, database instruction files and templates with examples are archived in a document subdirectory and require the user to have Microsoft Word© to view the document.

Target Users

Commissioning providers and building owners of all levels of experience are the expected users. The library is intended to help reduce the amount of effort in developing commissioning tests from scratch, thereby streamlining the process. Experienced commissioning providers are likely

to use the library in locating special test protocols, as the foundations for developing their own tests and for a better understanding of the cost effectiveness of selected procedures.

Owners and developers are a likely group to target as indirect users of the library. They can be encouraged to specify that the commissioning providers they hire use the CPTL (where appropriate) to identify test protocols for use in the development of building-specific tests. This will help ensure the use of a more standardized process.

Important CTPL Features

The library will enable commissioning providers to:

- Identify exemplary public domain commissioning test protocols for each system.
- Select templates for developing test protocols.
- Retrieve public domain documents related to commissioning.
- Search for information based on key words and other such criteria.

The library will provide the basis for well-written verification checks and functional tests to serve as examples for the commissioning industry[1].

Feedback from 2001 NCBC

A working session was held at the National Conference on Building Commissioning (NCBC) 2001 entitled "*The Commissioning Test Protocol Library: How to ensure quality usage?"* and focused on:

- An overview of Ken Gillespie's work including a demonstration of some of the information available in the database.
- A brief overview of PECI's and LBNL's current development concept for the educational component for the library.
- Discussion and feedback from the participants.

In general, the discussion was positive and indicated that the participants felt that the CTPL is of value and were interested in obtaining a copy as soon as it is available. Participants also felt that an educational component would be helpful and should include practical information and concrete examples.

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[1] Additional information regarding the CTPL can be found in the proceedings from the 9th National Conference on Building Commissioning in a paper entitled *Library of Commissioning Test Protocols*. Copies of the current version of the library can be obtained by contacting Ken Gillespie at KLG2@pge.com.

One of the more difficult aspects of developing the educational component will be deciding where to stop and/or what general level of user knowledge should be assumed in writing the guide. The process is considered a significant undertaking.

It was agreed that a master protocol for users to "whittle down" to create the protocol they need is a better approach than building up a protocol from smaller components. This is also the approach agreed upon by the PIER team.

Subsequent to the conference, the library was to attendees of the NCBC working session and other interested parties. A questionnaire on user's protocol requirements and product functionality needs was included with the distribution. The feedback from the questionnaire was used by PG&E to further enhance the functionality and content of the early release of the CTPL as reflected by the current version (Release 1.3). This work included the development of two very useful protocols targeted at testing economizer systems and DDC control systems. In addition to filling critical gaps in the available protocols in the library, the development of these procedures tested the development templates included in the library. When PG&E reviewed their library of existing commissioning protocols to determine potential gaps, they determined that public domain documents need to be developed for the following systems: condenser water treatment, economizer control, outside air ventilation, building pressurization/infiltration, HVAC air handler capacity, air diffuser dumping and energy management hardware and software.

PG&E is also testing the library on three projects under its Savings By Design program and on PG&E's Building and Land Services projects. These projects will use the library as the source for developing the functional test requirements for their systems.

Current Structure of the FT Guide

The Guide is currently developed as Microsoft Word® Master Document, which is a standard Word® feature. Due to the amount of content, the Guide could easily be overwhelming to the user if some easy to understand and use navigational tool was not provided. The Master Document approach allows the numerous documents that comprise the chapters of the Guide to be viewed and navigated as if they were a seamless document. The hyper links in the Master Document table of contents will take you to the area selected. Each section will contain a more detailed table of contents that will allow the user to easily navigate through the section. Hyperlinks on key words in each section will also do this and/or provide a means to take the user to related information in other sections. This is illustrated in Figure 1. These navigation features will be enhanced by the Visual Basic programming to take the user to the functional tests associated with each section so they can view them interactively and customize them to their projects. This feature will be discussed in greater detail later in the paper.

Content

The following tabulation enumerates the content and structure currently proposed for the Guide. Subsequent sections of the paper will discuss features of some of these sections.

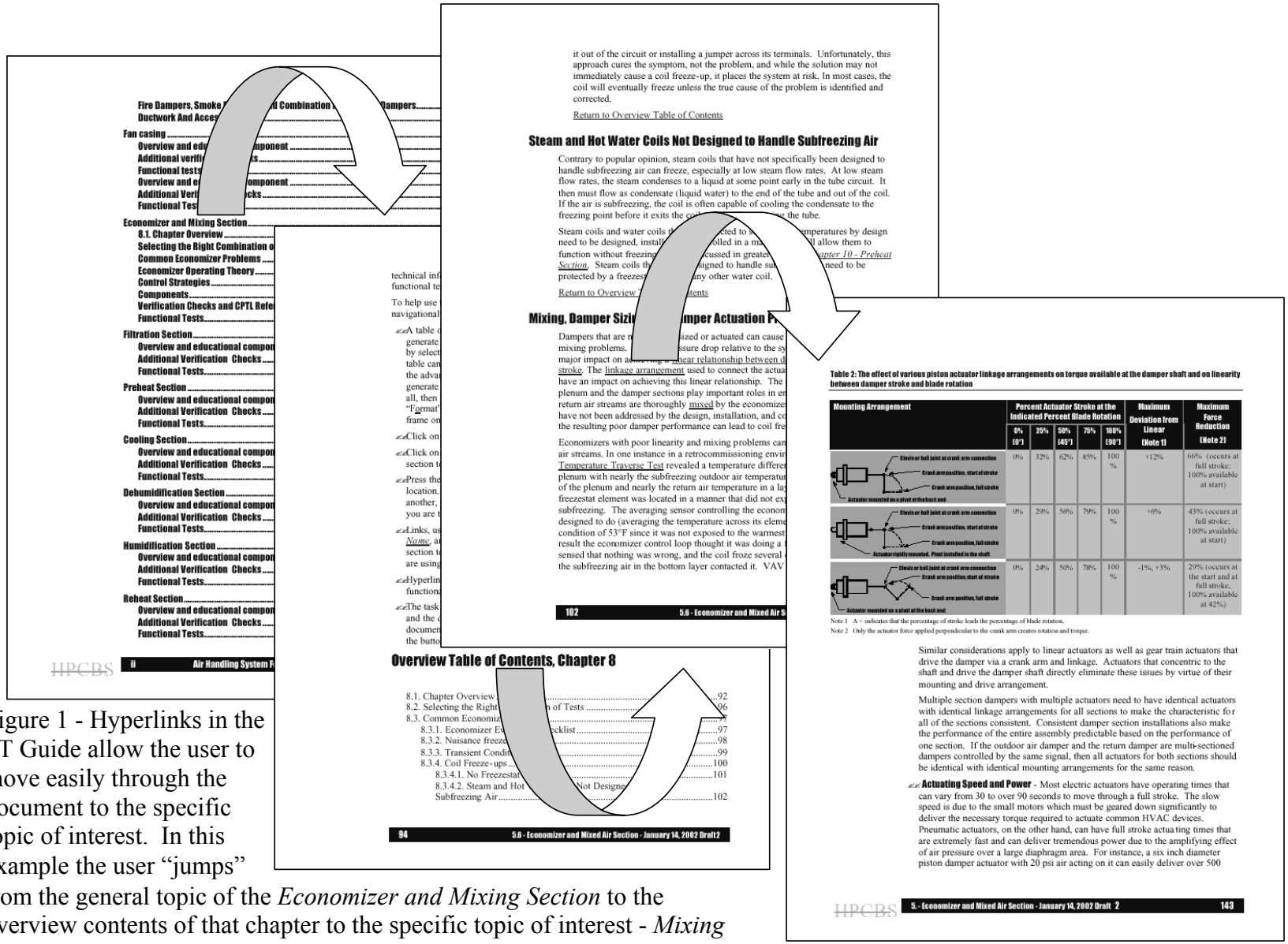


Figure 1 - Hyperlinks in the FT Guide allow the user to move easily through the document to the specific topic of interest. In this example the user "jumps" from the general topic of the *Economizer and Mixing Section* to the overview contents of that chapter to the specific topic of interest - *Mixing Damper Sizing and Actuation* - in two mouse clicks. One additional mouse click takes them to related information.

- Table of Contents
- Chapter 1 - Introduction
- Chapter 2 - Guidelines for Control and Monitoring points
- Chapter 3 - Guidelines for Control Algorithm Design Chapter 4 - System Configurations
- Chapter 5 - General Functional Testing Information
- Chapter 6 - Outdoor Air Intake Section
- Chapter 7 - Fan Casing Section
- Chapter 8 - Economizer and Mixing Section
- Chapter 9 - Filtration Section
- Chapter 10 - Preheat Section
- Chapter 11 - Cooling Section
- Chapter 12 - Dehumidification Section
- Chapter 13 - Humidification Section
- Chapter 14 - Reheat Section
- Chapter 15 - Warm-up Section
- Chapter 16 - Fan and Drive Systems
- Chapter 17 - Distribution System
- Chapter 18 - Terminal Equipment
- Chapter 19 - Return, Relief, and Exhaust Systems
- Chapter 20 - Energy Recovery Equipment
- Chapter 21 - Scrubbers
- Chapter 22 - Smoke Control System
- Chapter 23 - Integrated Control Functions
- Chapter 24 - Appendix A - History of the CTPL
- Chapter 25 - Appendix B - Glossary
- Chapter 26 - Appendix C - Resources
- Chapter 27 - Appendix D - Sample Calculations
- Chapter 28 - Appendix E - Sample Control Sequences
- Chapter 29 - Appendix F - Smart Alarms
- Chapter 30 - Appendix G - Design Intent
- Chapter 31 - Appendix H - Periodicals

System Based Approach to Testing

The guide uses a systems approach to testing since ultimately, it is the integrated interaction of all of the components in an air handling system that must be tested and made to function properly if the design intent of the project is to be achieved. Towards that end, the guide is being developed with a chapter structure that leads the user from basic concepts such as control an monitoring point selection and functional testing basics through each major subassembly or component associated with an air handling system concluding with a chapter on integrated

control functions. This information is supplemented by a set of appendices included with the guide and links to the CTPL. Chapter 4 is dedicated to a discussion of common system configurations and includes illustrations and point list recommendations for each of the types discussed.

Control and Monitoring Information

At one point in time, the CEC was funding a separate PIER project targeted at developing a Control and Monitoring Guide for Designers. The intent of the document was to provide information to guide designers in the specification and detailing of control and monitoring points so that their projects included:

- Basic points required for their control sequences.
- Supplemental points necessary for trending and monitoring functions associated with commissioning and operations.
- Well-specified sensor and requirements to ensure that the accuracy and installation of the sensors reflected the design and operating needs of the systems.
- Well-written control sequences to ensure that their design intent was fully realized.

This project was being developed on a parallel track with the FT Guide. As work on both projects progressed, it became apparent that they were highly inter-related. The more one is exposed to the issues, the more difficult it becomes to segregate design from the commissioning and operational environment. The development team realized that the designers need to understand the real world operating environment that their systems will see (i.e. the commissioning agent's and facilities engineering world) and formulate their designs to address those needs in addition to the direct design condition needs. Similarly, people involved in the commissioning and operations end of the industry needed to understand and become involved in the designer's world. By learning about and becoming proactive in the design process, commissioning and facilities personnel can thwart many operational and efficiency issues before they become problems. They also can develop an insight into the design parameters associated with the projects they are working on, which will prove beneficial in documenting the project's design intent and ensuring that the operating systems meet it.

As a result, the *Control and Monitoring Guide* was integrated with the *Functional Testing Guide* in an effort to emphasize the inter-relationship and make the necessary information available to all concerned parties. Chapters 2, 3 and 4 reflect the bulk of the information that was originally intended for the Monitoring Guide. The current structure will allow these chapters to be extracted to function as a stand-alone document if necessary.

Air Handling Unit Testing Chapters

The bulk of the guide is dedicated to educational content targeted at the theory and cost/benefit relationships associated with functional testing of air handling equipment. *Chapter 8 -*

Economizer and Mixing Section was selected as a development template for the technical chapters to allow the FT Guide developers to understand what a typical chapter should look like and how it should work. Currently, it is an 80-85% draft that is out for review by the Technical Advisory Group associated with the project[2].

This chapter was selected for development purposes because economizers, while simple in concept, actually have some fairly complex theory and implementation issues associated with them. In some cases, the issues will vary from local to local. For instance, in San Francisco or the in Willamette Valley in Oregon, coil freeze-ups and freezestat issues are relatively rare. However, if one travels East towards the Sierra Nevada's or Spokane respectively, these issues are quite common. In other cases, the issues are consistent, but the details associated with them vary from local to local. For example, one of the most common misunderstandings that the developers encounter in the field relates to how to set and test the enthalpy change-over on an economizer. Some estimate that 50% of the package rooftop units with economizers have this magic little enthalpy switch shipped with them, specified with the best of intent to optimize energy consumption. But seldom do people seem to know how to set the switch for their local environment and how to check them once they are set. As a result, people involved in retrocommissioning and operations tend to see them defeated or non-operational. Chapter 8 includes content that addresses both of these issues and many others related to economizer theory and function.

This broad spectrum of issues and applicability provided an opportunity for the team to develop a chapter structure that would allow the user to target the problems of interest to them in their specific test situation and fairly quickly glean the knowledge base necessary to optimize tests for their specific project. It also helped them understand how to structure the chapter in a manner that would help someone who might not "know what they don't know" discover the specific answers to their initial questions as well as discover other issues they may want to consider. For example, the freezing issues presented for the economizer system are important for the higher altitudes in California. But, someone who has spent most of their time working along the coast may not be aware of them and, with out guidance, may approach the problem of designing, starting up and commissioning their first system in the mountains in a manner similar to what they might use in the Bay area. If they have little or no knowledge of the cold climate issues associate with economizers, they will in all likelihood gain that knowledge the hard way on their first cold climate project, often to their own detriment and possibly to the detriment of the commissioning industry in general. This same individual, developing their design, test plan and procedures by working through the Guide is quite likely be exposed and alerted to many of the cold weather issues associated with economizers. The *Economizer Evaluation Checklist* (presented early in the chapter) is designed to alert the user to potential efficiency and operational issues and link them directly to the appropriate sections of the chapter that contain

[2] The development process associated with products developed by the CEC under the PEIR program involves a peer review component where in a group of experts in the field review, comment and direct the product development at several points in the cycle. This group is called a Technical Advisory Group or TAG.

additional information. The hyper linking capabilities of Word® discussed previously made this fairly easy to accomplish once the team understood the protocol.

The technical issues discussed in the previous paragraphs have been presented in the context of California and the Pacific Northwest, the home territory of the development team and the funding source. But, they are also significant on a national scale, and since there is reason to believe that this document will eventually be distributed all over the United States if not internationally, even though it is being funded by California public benefit money. Thus the development team felt it was important to structure the Guide in a manner that addressed a broad spectrum of application environments.

One of the concepts behind the FT Guide is that it should include model functional tests to assist users in developing and executing their own functional tests specific to the projects they are working on. These model functional tests are envisioned as supplements and enhancements to the information in the CTPL that will allow the user to identify and adapt the best processes in the CTPL to their project based on the supporting educational material. Tables that outline the energy efficiency and other benefits as well as costs, instrumentation requirements, acceptance criteria, and potential problems and caution are included with these tests where appropriate as is supplemental educational material. Visual Basic programming is being developed and packaged into the Guide structure to allow the following features to be implemented with regard to these tests and the CTPL.

- The user will be able to "jump" from the educational material related to a particular test to the test itself. In general terms, the VBA code will query the CTPL database to located the appropriate procedure and then open the procedure as a Word® document for the user to view.

- The user will be able to save the test as a Word® document to their personal library of test procedures or to a directory associated with a specific project, or both. This will preserve the original version contained in the CTPL for future reference. The personal copy, created by the user, will then be available for modification using standard word processing techniques. This will allow the user to format the test to match their standards, edit the test as required to meet the specifics of their project, or create totally new test procedures built from the ones contained in the Guide and the CTPL.

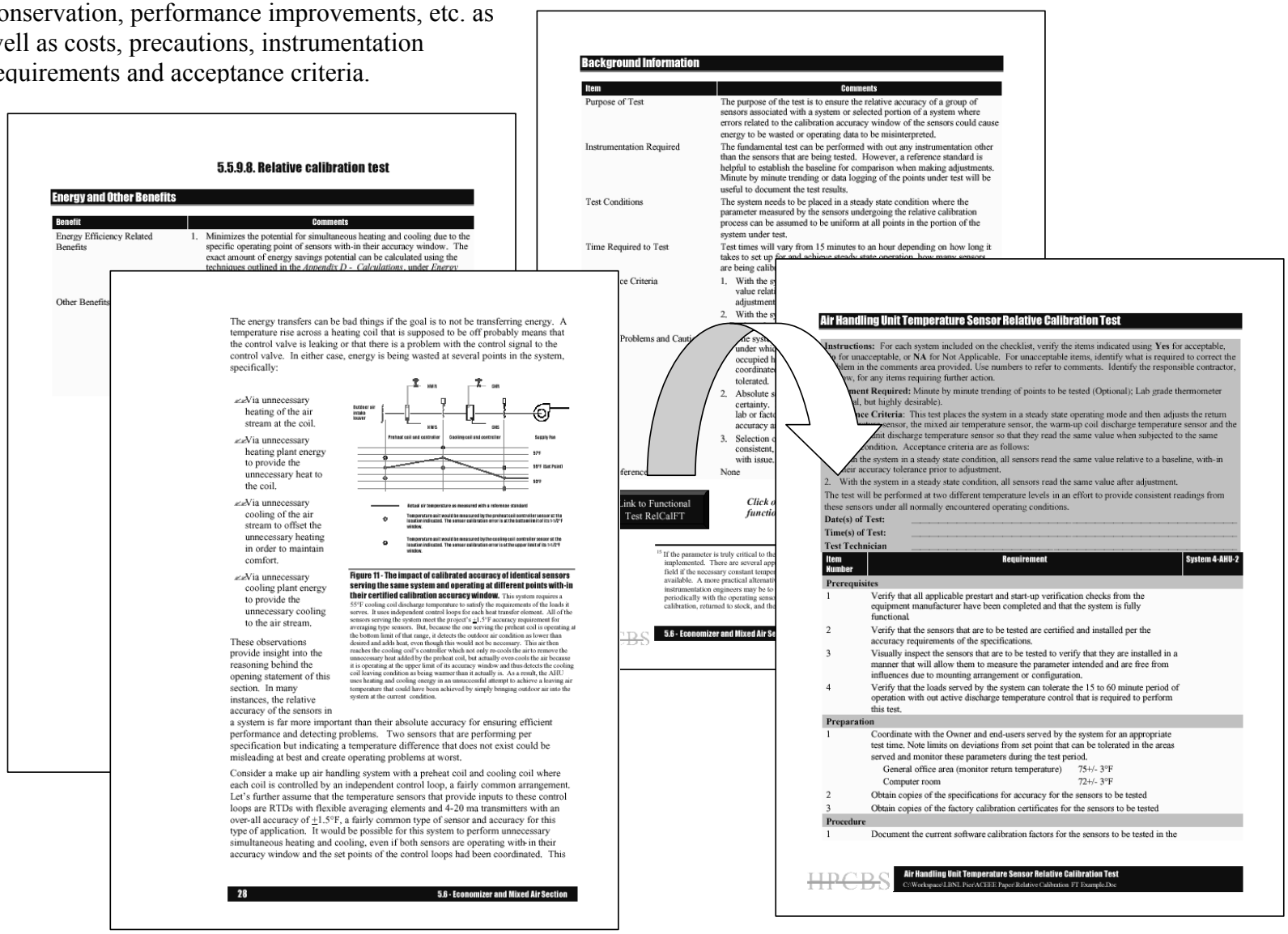
- The user will able to access the customized procedures for future projects via the FT Guide in the same manner in which they accessed the model procedures from the CTPL and Guide when they first started using the tool.

Many of these concepts are illustrated in Figure 2.

Supplemental Appendices

The guide also includes supplemental appendices that contain supporting information for the main chapters.

Figure 2 - Each test will include tables stating its benefits in terms of efficiency, resource conservation, performance improvements, etc. as well as costs, precautions, instrumentation requirements and acceptance criteria.



5.5.9.8. Relative calibration test

Energy and Other Benefits

Benefit	Comments
Energy Efficiency Related Benefits	1. Minimizes the potential for simultaneous heating and cooling due to the specific operating point of sensors with-in their accuracy window. The exact amount of energy savings potential can be calculated using the techniques outlined in the *Appendix D - Calculations*, under *Energy*
Other Benefits	

Background Information

Item	Comments
Purpose of Test	The purpose of the test is to ensure the relative accuracy of a group of sensors associated with a system or selected portion of a system where errors related to the calibration accuracy window of the sensors could cause energy to be wasted or operating data to be misinterpreted.
Instrumentation Required	The fundamental test can be performed with out any instrumentation other than the sensors that are being tested. However, a reference standard is helpful to establish the baseline for comparison when making adjustments. Minute by minute trending or data logging of the points under test will be useful to document the test results.
Test Conditions	The system needs to be placed in a steady state condition where the parameter measured by the sensors undergoing the relative calibration process can be assumed to be uniform at all points in the portion of the system under test.
Time Required to Test	Test times will vary from 15 minutes to an hour depending on how long it takes to set up for and achieve steady state operation, how many sensors are being calib
ce Criteria	1. With the sy value relati adjustment 2. With the sy
Problems and Cauti	ne syst under whi occupied h coordinate tolerated. 2. Absolute s certainty. lab or facto accuracy a 3. Selection c consistent, with issue.
ference	None

Link to Functional Test RelCalFT

Click o functio

The energy transfers can be bad things if the goal is to not be transferring energy. A temperature rise across a heating coil that is supposed to be off probably means that the control valve is leaking or that there is a problem with the control signal to the control valve. In either case, energy is being wasted at several points in the system, specifically:

- Via unnecessary heating of the air stream at the coil.
- Via unnecessary heating plant energy to provide the unnecessary heat to the coil.
- Via unnecessary cooling of the air stream to offset the unnecessary heating in order to maintain comfort.
- Via unnecessary cooling plant energy to provide the unneeessary cooling to the air stream.

Figure 11 - The impact of calibrated accuracy of identical sensors serving the same system and operating at different points with-in their certified calibration accuracy window. This system requires a 55°F cooling coil discharge temperature to satisfy the requirements of the loads it serves. It uses independent control loops for each heat transfer element. All of the sensors serving the system meet the project's ±1.5°F accuracy requirement for averaging type sensors. But, because the one serving the preheat coil is operating at the bottom limit of that range, it detects the outdoor air condition as lower than desired and adds heat, even though this would not be necessary. This air then reaches the cooling coil's controller which not only re-cools the air to remove the unnecessary heat added by the preheat coil, but actually over-cools the air because it is operating at the upper limit of its accuracy window and thus detects the cooling coil leaving condition as being warmer than it actually is. As a result, the AHU uses heating and cooling energy in an unsuccessful attempt to achieve a leaving air temperature that could have been achieved by simply bringing outdoor air into the system at the current condition.

These observations provide insight into the reasoning behind the opening statement of this section. In many instances, the relative accuracy of the sensors in a system is far more important than their absolute accuracy for ensuring efficient performance and detecting problems. Two sensors that are performing per specification but indicating a temperature difference that does not exist could be misleading at best and create operating problems at worst.

Consider a make up air handling system with a preheat coil and cooling coil where each coil is controlled by an independent control loop, a fairly common arrangement. Let's further assume that the temperature sensors that provide inputs to these control loops are RTDs with flexible averaging elements and 4-20 ma transmitters with an over-all accuracy of ±1.5°F, a fairly common type of sensor and accuracy for this type of application. It would be possible for this system to perform unnecessary simultaneous heating and cooling, even if both sensors are operating with-in their accuracy window and the set points of the control loops had been coordinated. This

28 5.6 - Economizer and Mixed Air Section

5.6 - Economizer and Mixed Air Se

Air Handling Unit Temperature Sensor Relative Calibration Test

Instructions: For each system included on the checklist, verify the items indicated using **Yes** for acceptable, for unacceptable, or **NA** for Not Applicable. For unacceptable items, identify what is required to correct the lem in the comments area provided. Use numbers to refer to comments. Identify the responsible contractor, s, for any items requiring further action.

ment Required: Minute by minute trending of points to be tested (Optional); Lab grade thermometer al, but highly desirable).

nce Criteria: This test places the system in a steady state operating mode and then adjusts the return sensor, the mixed air temperature sensor, the warm-up coil discharge temperature sensor and the nit discharge temperature sensor so that they read the same value when subjected to the same condition. Acceptance criteria are as follows:

1. With the system in a steady state condition, all sensors read the same value relative to a baseline, with-in eir accuracy tolerance prior to adjustment.
2. With the system in a steady state condition, all sensors read the same value after adjustment.

The test will be performed at two different temperature levels in an effort to provide consistent readings from these sensors under all normally encountered operating conditions.

Date(s) of Test:

Time(s) of Test:

Test Technician

Item Number	Requirement	System 4-AHU-2
Prerequisites		
1	Verify that all applicable prestart and start-up verification checks from the equipment manufacturer have been completed and that the system is fully functional.	
2	Verify that the sensors that are to be tested are certified and installed per the accuracy requirements of the specifications.	
3	Visually inspect the sensors that are to be tested to verify that they are installed in a manner that will allow them to measure the parameter intended and are free from influences due to mounting arrangement or configuration.	
4	Verify that the loads served by the system can tolerate the 15 to 60 minute period of operation with out active discharge temperature control that is required to perform this test.	
Preparation		
1	Coordinate with the Owner and end-users served by the system for an appropriate test time. Note limits on deviations from set point that can be tolerated in the areas served and monitor these parameters during the test period. General office area (monitor return temperature) 75+/- 3°F Computer room 72+/- 3°F	
2	Obtain copies of the specifications for accuracy for the sensors to be tested	
3	Obtain copies of the factory calibration certificates for the sensors to be tested	
Procedure		
1	Document the current software calibration factors for the sensors to be tested in the	

HPCBS Air Handling Unit Temperature Sensor Relative Calibration Test
C:\Workspace\LBNL Pier\ACEEE Paper\Relative Calibration FT Example.Doc

Visual Basic programming will allow the user to click on a button and be moved to the test under consideration in the CTPL. From that point, the user can save the test to their own directories and customize it as necessary for their use.

- *Appendix A - History of the CTPL* will contain information very similar to the information in the first section of this paper.

- *Appendix B - Glossary* will contain a glossary of key words, terms and acronyms used throughout the guide.

- *Appendix C - Resources* will contain a list of books, articles, web links, and other information that can be researched by the user to supplement the information presented in the guide.

- *Appendix D - Sample Calculations* will contain sample calculations for some of the techniques referenced in the guide chapters. Usually, these will be energy savings estimating or performance projection techniques. Links to spreadsheets that provide a template for the calculations discussed are currently envisioned as being a part of the package.

- *Appendix E - Sample Control Sequences* will contain illustrative examples of detailed control sequences for some of the system configurations discussed in Chapter 4 or some of the control problems identified in the other chapters of the guide.

- *Appendix F - Smart Alarms* will contain suggested logic for smart alarms that take advantage of the logic capabilities of DDC technology to generate an alarm based on the state of several inputs. Many of the alarms will be targeted at identifying potentially energy wasting operating modes that might otherwise go undetected.

- *Appendix G - Design Intent* will contain forms and information to assist designers and commissioning agents in identifying the necessary information required to develop and implement the design intent for an Owner's air handling equipment.

- *Appendix H - Periodicals* will contain a list of periodicals that are useful references for anyone involved in the design, operation and commissioning of HVAC equipment, especially air handling equipment.

Next Steps

Funding in the current research cycle is not sufficient to allow development of the Guide to the full extent visualized by the development template realized in the economizer chapter. However, it is sufficient to allow the current goals to be targeted.

- Complete the development of the first 5 chapters of the FT Guide as currently envisioned; specifically:

    - *Chapter 1 - Introduction*
    - *Chapter 2 - Guidelines for Control and Monitoring Points*
    - *Chapter 3 - Guidelines for Control Algorithm Design*
    - *Chapter 4 - System Configurations*

  - *Chapter 5 - Functional Testing Basics*
- Finalize *Chapter 8 - Economizer and Mixing Section* based on comments from the TAG after reviewing the current draft.

- Develop the following chapters in detail based on the chapter 8 template:

  - *Chapter 18 - Terminal Equipment*
  - *Chapter 23 - Integrated Control Functions*

  These chapters have been targeted based on the development team's belief that they have the potential to deliver the most benefit in terms of energy efficiency and operational improvements for the money spent. The development of *Chapter 23* will be in relationship to the other chapters that are developed in detail. This chapter will need to be revisited along with the development of other chapters as funding becomes available to include the integration functions associated with them.

- Finalize *Chapter 6 - Outdoor Air Intake Section*. This is the chapter that was used to prototype some of the original Guide concepts when the Guide specifications were developed. While the testing and educational material associated with it does not have the potential energy savings impact associated with Chapters 18 and 23, much of the development work is already done and is included in the current draft of the Guide. Completing the chapter will take advantage of the development work already completed and will also provide useful information and outline testing strategies for components common to other portions of air handling systems including smoke and fire dampers, and duct leakage testing. These outlined strategies can be developed into supplemental functional tests to "fill holes" in the CTPL at a later date as funding becomes available.

- Develop overviews for the remaining chapters. These overviews would highlight key considerations including some sort of cost benefit statements relating to the section in question. They would also serve as a springboard for the user to launch into any relevant CTPL procedures associated with the section. Ultimately, these overviews will serve as a framework for subsequent development efforts.

- Develop Appendix A through Appendix F and Appendix H information as it relates to the current level of chapter development. Like Chapter 23, these sections will need to be revisited as the detailed development work is funded for the chapters not included in the current funding cycle.

- Finalize Appendix G in its current form.